

**CALIFORNIA DIVISION OF MINES AND GEOLOGY
FAULT EVALUATION REPORT FER-200**

**LOS OSOS FAULT ZONE
San Luis Obispo County**

By
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INTRODUCTION

The Los Osos fault zone is a southwest-dipping fault zone which extends for approximately 12 miles (20 km) along the northern margin of the Irish Hills in the central coastal portion of San Luis Obispo County (Figure 1). It includes the older, steeply dipping Los Osos fault of Hall (1973a, b) and Hall and Prior (1975) as well as shallow and steeply dipping late Quaternary faults mapped by Nitchman (1988) and PG & E (1988). North of this west-northwest trending fault zone lie the structurally lower Morro Bay and Los Osos Valley. To the northwest, the Los Osos fault zone probably continues offshore for another 6 to 8 miles (10-13 km) to join the north-northwest trending Hosgri fault zone. Southwest of San Luis Obispo the Los Osos fault zone ends as it swings or steps right to merge with the Edna fault (Hall, 1973a). The onshore portion of the fault zone corresponds with what Lettis and Hall (1988) and PG & E (1988) refer to as the "Irish Hills segment" of the fault system which forms the Quaternary structural boundary between the San Luis Range and the lower terrain to the north (Figure 2). Although portions of this fault system may have experienced some strike-slip displacement in the late Cenozoic, it is believed to have been predominantly a zone of reverse faulting for the past half-million years (PG & E, 1988).

This evaluation was initiated in response to reported evidence for Holocene activity along the Los Osos fault zone, (Lettis and Hall, 1988; PG & E, 1988). This area is experiencing continued urban growth with consequent potential for conflict between fault-rupture hazards and residential construction. The purpose of this evaluation is to determine if any of the traces of the Los Osos fault zone meet the criteria of "sufficiently active and well-defined" and warrant zoning under the Alquist-Priolo Special Studies Zone Act (Hart, 1985).

SUMMARY OF AVAILABLE DATA

The Los Osos fault was first mapped by Hall (1973a,b, and Hall and Prior, 1975) and named in the published literature by Hall and Prior (1975). This strand of the Los Osos fault zone lies largely within or bounds Franciscan volcanic rocks, graywacke and serpentinite, and in some areas separates the Franciscan rocks from the Pleistocene Paso Robles Formation. It runs roughly parallel to Los Osos Valley Road from south of Turri Road eastward, nearly to U.S. Highway 101.

Recent studies, related to the Diablo Canyon Long Term Seismic Program (Mezger and others, 1987; Weber and others, 1987; Lettis and Hall, 1988; Nitchman, 1988; PG & E, 1988), have identified faulting valleyward of the Los Osos fault of Hall and have discussed this broader fault zone as part of a longer, segmented, fault system which controls the northern margin of the San Luis-Pismo Structural Block. The segments discussed (Figure 2) are the Estero Bay segment (extending offshore to the Hosgri fault zone), the Irish Hills segment (along the north side of the Irish Hills), the Lopez Reservoir segment and the Newsom Ridge segment. (The latter two segments parallel or incorporate the Edna fault). The four segments are distinguished, largely, according to their relative activity as indicated by geomorphic characteristics as well as limited corroborating geologic data.

Evidence of this system as a Quaternary structural boundary include well-preserved elevated marine terraces at the western end of the range juxtaposed, across the fault zone, with the subsiding Morro Bay area (Weber and others, 1987; PG & E, 1988). Also, the mountains south of the Los Osos and Edna fault zones have risen under several antecedent drainages (San Luis Obispo Creek, Pismo Creek and Arroyo Grande Creek). Fluvial terraces along Arroyo Grande Creek (Nitchman, 1988) and along San Luis Obispo Creek (PG & E, 1988), when projected north of the fault system, are tens of meters higher than the valley floor or other possibly correlative horizons.

Although Lettis and Hall (1988), Nitchman (1988) and PG & E (1988) have applied the name "Los Osos fault zone" to the entire frontal system (including part of the Edna fault) I am restricting that name to the segment along the Irish Hills (which includes the Los Osos fault of Hall and Prior, 1975), and its possible, on trend, extensions.

Possible westward extensions of the Los Osos fault zone run south of Los Osos and offshore (to intersect the Hosgri fault zone), and also west-northwest along the north side of Morro Bay (Figure 2). The more southerly extension is supported by offshore topography but there is no clear evidence

for Holocene displacement on either trend, although the northern trace "may displace post-Wisconsin sediment" (PG & E, 1988, Table 2-14).

To the southeast, the fault zone may die out, on trend, along the southwestern margin of Laguna Lake or it may bend or step right to join the Edna fault zone, along what PG & E (1988) and Lettis and Hall (1988) call the Lopez Reservoir segment (which extends to Arroyo Grande Creek). N.T. Hall and W.R. Lettis (personal communication, 1988) suggested that the main active thrust of the Los Osos fault zone may lie valleyward, toward the margin of Laguna Lake and Mezger and others (1987) proposed that an unmapped northeastern-most strand of the fault zone "may form the southwestern margin of Laguna Lake". Nitchman (1988) and PG & E (1988) suggested that the lake may be tectonically impounded.

Lettis and Hall (1988) and PG & E (1988) believe that, among the four segments of the fault system, the Irish Hills segment, between Morro Bay and San Luis Obispo Creek, shows evidence of the most recent activity and the highest slip-rate (up to 0.4 mm/yr, vertical) based on features delineated on PG & E's (1988) Plate 16 (Plate 1 herein) as well as its location at or near the base of a moderately dissected, moderately steep and linear range front. The other three segments do not appear as active. The traces of the Estero Bay segment do not bound a major range as do the other segments. The Lopez Reservoir segment is not as well-defined as a range-bounding fault, has weaker and older-looking geomorphic expression and is estimated to have a vertical slip rate of less than 0.1 mm/yr. Limited trenching along this segment found no evidence for Holocene faulting, although one fault was traceable into a B soil horizon as, what was interpreted as, a relict feature (N.T. Hall, personal communication, 1988). The Newsom Ridge segment is mapped within, rather than at the margin of, a deeply dissected range and is estimated to have a vertical slip-rate less than 0.1 mm/yr, if it is active at all.

Nitchman (1988) mapped a short late-Quaternary fault, exposed in Los Osos Creek, which he named the Italiano fault (see location on Plate 1). This northeast trending fault was interpreted as a left-lateral tear fault related to the Los Osos fault zone. It offsets fluvial deposits dated from ~22,000 to ~28,000 years old (N.T. Hall, personal communication, 1988), but is overlain by unbroken, possibly Holocene, fluvial gravels. Nitchman (1988) states "the offset is on the order of 50 cm" but he is probably referring only to the vertical separation which would be visible in the stream bank exposure.

Detailed Studies

A zone of discontinuous and en echelon features suggestive of Holocene faulting was recorded along the Los Osos fault zone by Nitchman (1988) and PG & E (1988, Plate 16 - see Plate 1 herein). These features include tonal and vegetational lineaments, springs and seeps, linear and deflected drainages and topographic benches, breaks-in-slope and escarpments. Trenching of some of these features has produced data at three localities supportive of Holocene faulting (N.T. Hall, personal communication, 1988; Nitchman, 1988; PG & E, 1988). See Plate 1 or Figure 4, herein, for trench locations.

At Ingley trench T-1 faulting has occurred along what may be a back thrust in the upper block above the main fault trace. A colluvial unit dated at $28,450 \pm 550$ ybp is the youngest material actually faulted in this trench, however Holocene alluvium (2420 ± 90 ybp and 2520 ± 50 ybp) appears to be ponded behind the fault, suggesting more recent tectonic deformation. This fault is presumed to be the same one exposed in a stream cut a short distance to the west. Farther out from the range front, Ingley trench T-2 was excavated at the base of a northeast-facing, 6-meter-high escarpment. This trench exposed the presumed main active trace of the Los Osos fault zone, expressed as a zone of several low-angle thrust faults. Two of these faults displaced a surficial colluvial and soil horizon which yielded (from a locality downslope) an MRT date of 1840 ± 60 ybp. Cumulative apparent displacement of a lower paleosol horizon (estimated to be 15-30 thousand years old) amounted to 0.6 ± 0.3 m vertical, and 4.1 ± 0.2 m horizontal (compressional).

To the southeast of the Ingley trenches are Cuesta trenches T-1, T-2 and T-3. These excavations explored several north-facing topographic scarps. Although faulting was found in Cuesta trenches T-2 and T-3 the sense of vertical stratigraphic separation was of the wrong sense to produce the observed scarps, and in trench T-2 the observed northeast-dipping reverse fault coincided with the upper edge of the northeast-facing scarp. In Cuesta trench T-3 the same northeast-dipping reverse fault corresponded somewhat better in location to the scarp but still showed the reverse sense of stratigraphic separation. A second northeast-dipping reverse fault was not associated with a scarp. A third fault at the northern end of trench T-3 was a rootless, south-dipping thrust fault which was visible in the soil and appeared to truncate a krotovina. Soil filling this krotovina yielded a MRT date of 2516 ± 10 yrs (N.T. Hall, personal communication, 1988). This third fault may correspond with a scarp and/or vegetational lineament observed by PG & G (1988) and also noted in the course of my reconnaissance and interpretation. The thrust

fault is offset by a steep northeast-dipping reverse fault which stops at the thrust. All of the northeast-dipping reverse faults exposed in the Cuesta trenches place Franciscan rocks on the north against younger colluvial units (tentatively identified as Paso Robles Formation) on the south.

SEISMICITY

There have been only a few low-magnitude (<3.0) earthquakes recorded which might be associated with the south-dipping Los Osos fault zone (Figure 3). They have not been prevalent enough, however, to give definition to the fault zone, although the plot of 1980-1988 epicenters does suggest activity offshore and toward the eastern end of the zone.

The largest earthquakes in the vicinity of the Los Osos Valley have been:

1. 1830 ~M5 vicinity of San Luis Obispo
2. 12/1/1916 ~M5 Avila
3. 10/20/1917 ~M5+ Arroyo Grande

(Source of data: PG & E, 1988)

PHOTO INTERPRETATION & FIELD OBSERVATIONS

Two sets of aerial photographs were used for this evaluation. A set of low-sun-angle photos at a scale of 1:14,000 was flown in February 1987 for the University of Nevada at Reno. The Los Osos fault zone is covered by one strip running parallel to the zone. A set of USDA photos at a scale of ~1:21,000, flown in September 1956 and August - September 1957, covers the Los Osos fault zone as well as the Lopez Reservoir segment of PG & E (1988) and consists of a series of north-south flight lines. The scale and low-sun-angle of the UNR flight brings out detail on many topographic features while the older vintage of the USDA photos has allowed observation of details which have since been masked by agriculture and construction.

Many of the strictly tonal features observed by PG & E (1988) were not verifiable in the photo sets used for this evaluation. Most of the topographic and many of the vegetational lineaments were, however, observable. Features considered to be older landforms (and possibly merely fault-line features) were not emphasized in this study unless they provided continuity or extent to fresher-looking features.

Most features along the Los Osos fault zone were field checked on September 14-16, 1988. The most impressive features are those which define a relatively continuous trend from localities 1 through 11 (Figure 4). Locality 12 represents a possible extension of this trend. Localities 13 through 19

define a left-step in the fault zone along a somewhat less-fresh looking fault zone segment, with a tenuous extension along locality 20. Other features, along the Los Osos fault trace of Hall (1973a) and Hall and others (1979) and along the Lopez Reservoir segment, are primarily features such as linear drainages, sidehill benches and breaks-in-slope. These features lack the freshness and sharpness of those at localities 1 through 21 and are probably fault-line features accentuated by differential erosion in sheared bedrock or at lithologic discontinuities.

The proposed tectonic impoundment of Laguna Lake (Mezger and others, 1987; PG & E, 1988) is not considered necessary. Sediment from the high, steep mountains and larger drainage of San Luis Obispo Creek upstream of the San Luis Valley may have been able to overwhelm the drainage of the smaller gentler valley containing Laguna Lake.

This evaluation did not look in detail at the segments of the fault system to the southeast since no evidence has been reported by PG & E (1988) or others to suggest Holocene activity. A brief study of 1956/1957 USDA air photos (~1:21,000) did not detect any fresh-looking or clearly tectonic fault morphology along PG & E's (1988) Lopez Reservoir segment.

All numbered localities are discussed in greater detail below.

1. A gentle swale (sidehill bench) visible in 1956 photo (USDA AXH-11R-59) may be differential erosion along bedding but aligns with stronger features to the northwest. This feature now appears to underlie a street rather than houses (except at the western edge of the existing residential development).
2. Moderately subdued scarps above the existing development may be a result of differential weathering of contrasting Franciscan lithologies.
3. This distinct scarp is prominent also as a ground-moisture boundary. Seeps or marshy ground exist seasonally where gullies cross the scarp, and green vegetation persists on the scarp while adjacent grasses have turned brown. The scarp angle measures between 17 and 18 degrees at a point where the scarp is 2 1/2 to 3 feet high. Scarp height increases westward to a maximum height of approximately 5 to 6 feet. Faults were exposed under this scarp in Cuesta trenches T-2 and T-3.
4. This relatively subdued feature is most distinct as a moisture barrier with green vegetation upslope of the lineament and evidence of seeps at gully crossings. Scarps are much lower than along feature 3 (maximum

- height approximately 2 1/2 feet at west end). Cuesta trench T-3 exposed a Holocene fault at this feature.
5. This relatively distinct scarp ends abruptly at a gully to the east and fades out only slightly less abruptly into a larger drainage on the west. Green vegetation persists later than adjacent grasses on this scarp as well as along one other lineament and a very subtle scarp farther to the south. Feature 5 has a height at one point of 5 1/2 to 6 feet with a slope angle of about 19 degrees. Cuesta trench T-1 crossed a scarp at the western end of this feature but did not expose a fault. It is possible that the topographic "step" crossed by the trench was a recessional fault-line feature. A test pit roughly 40 feet downslope intercepted Franciscan rocks several feet lower than in the trench, suggesting the possibility of an intervening fault.
 6. Faults, exposed in Sycamore Creek and in Ingley trench T-1 may continue eastward, along trend, expressed as a now-modified break-in-slope and a short subtle tonal lineament (USDA AXH-11R-59).
 7. This high (6 m) scarp is, apart from its height, rather subdued and eroded, with a face angle less than 10 degrees. It may be partly modified by stream erosion at the toe, and in fact gives more of the impression of being a meander bank than a fault scarp. Trenching (Ingley trench T-2), however, did reveal a set of shallow dipping thrusts at this locality giving credence to the interpretation as a fault scarp (PG & E, 1988, Plate 17).
 8. This scarp is well-defined at its eastern end, becoming more subtle on the adjacent property to the west, perhaps masked by agricultural activity. The eastern part of the scarp is from 4.5 to approximately 8 feet high and has a slope of 18 to 22 degrees. Evidence of a ground-moisture barrier includes persistent greener vegetation on the scarp and evidence of seeps where a gully crosses the feature. A short gentle south-facing scarp, south of the west end of the main scarp, is visible in older photography (USDA AXH-11R-59).
 9. This scarp is difficult to assess as it appear to have been modified by grading at the margin of a field. It now appears to be on the order of 10 feet high and a road at its western end makes an approximately 3.5 foot subdued vertical step across the trend. The western end has been obscured by agricultural grading, but was relatively well-defined on the 1956 photos (USDA AXH-11R-58).
 10. This feature is a clearly defined scarp in the 1956 photos (USDA AXH-11R-137) but has since become very subdued.

11. Also now masked by agriculture, this feature is, in part, a moderately distinct scarp in older photography (USDA AXH-11R-59).
12. Several linear drainages and saddles suggest possible extensions of the trend defined by features 1-11.
13. This moderately distinct scarp aligns with the heads of two gullies which may have developed from groundwater sapping, although seeps were not observed. Several lower scarps at the eastern end may be the product of landsliding; a partially backfilled trench on one scarp exposes soil downdropped against Paso Robles Formation(?) (on the south) along a distinct shear oriented N75W, 83N with vertical slickensides.
14. A possible closed depression on a broad ridge, below a break in slope, is visible on older air photos (USDA AXH-11R-137).
15. A distinct tonal lineament on 1956 photos (USDA AXH-11R-137) is still discernible on the 1987 UNR photos (1-173) as several small northeast and southwest facing scarps. These may be related to differential erosion, but no major contact has been mapped in this locality.
16. These persistent scarps roughly follow the mapped faulted contacts (Hall, 1973b) of a serpentinite body in the Franciscan. The present morphology (UNR 1-173) may be a result of differential erosion or renewed faulting.
17. This prominent escarpment along trend with the serpentinite contact, looks similar to but much more distinct than feature 7 (which is known to be accompanied by faulting).
- 18,19. Two, more subdued escarpments are parallel to feature 17, suggesting a left-stepping en echelon fault zone.
20. Although not previously attributed to faulting, this notably linear, dissected embankment lines up with the trend just described (localities 13 - 19 and may be a structural dam impounding Warden Lake.
21. The strength of this lineament lies in the consistent alignment of several different types of topographic and vegetational features, including distinct scarps across landslide terrain.

CONCLUSIONS

The Los Osos fault zone and related frontal faults to the southeast comprise a significant Quaternary fault system, based on their role as a structural boundary to the San Luis Range. The Los Osos fault zone is the most active portion of this system. This conclusion is based on a comparison of gross geomorphic features such as expression as a range-bounding fault. The most recent surface displacement has resulted from predominantly reverse faulting during Holocene time along

active or dormant, Los Osos fault traces mapped by Hall (1973b) and Hall and Prior (1975). The recently active trace consists of a discontinuous thrust toe and a more continuous break within the upper block of the thrust. The fault segment incorporating localities 3 to 11 is well-defined by distinct tonal and topographic alignments which are consistent with vertical displacements. Both tonal and topographic features at the eastern end of this segment have been shown by trench investigations to be clearly associated with faulting. Reasonably clear evidence of Holocene faulting was seen at two localities, Ingley trench T-2 and Cuesta trench T-3, and strongly suggestive data was recorded at Ingley trench T-1. Ambiguous and conflicting data within the trenches prevent a simple explanation of the fault mechanism involved in the more continuous trace. To the west, the active portion of the zone may step left to continue along pre-existing fault-controlled lithologic boundaries. The fault zone that includes localities 13 to 17, although presenting a moderately well defined zone of features, is not clearly active. Geomorphic features at localities 13 to 17 may be largely explainable as a result of differential erosion of the older faulted contacts.

RECOMMENDATIONS

Based on relative continuity and clarity of features as well as recent findings indicative of Holocene displacement, a portion of the Los Osos fault zone is considered to be sufficiently active and well-defined to warrant zoning under the Alquist-Priolo Act (Hart, 1985). It is recommended that the portion of the fault zone incorporating localities 3 to 11, and as highlighted in yellow on Figure 4, be zoned. The segments to the northwest (incorporating all other numbered localities) cannot be recommended for zoning at this time due to lack of clear evidence for Holocene surface rupture. Further investigation of these other features should, however, be encouraged where the likelihood of intercepting displaced Holocene units exists.

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*Reviewed & approved.
Earl W. Hart
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AERIAL PHOTOGRAPHS USED

USDA, black and white, vertical, scale ~1:21,000

9-10-56	AXH - 10R - 11 to 13
	AXH - 10R - 44 to 45
	AXH - 10R - 134 to 135
	AXH - 10R - 171 to 173
	AXH - 11R - 58 to 61
	AXH - 11R - 136 to 138
9-11-56	AXH - 12R - 65 to 67
	AXH - 12R - 84 to 86
	AXH - 12R - 105 to 107
8-8-57	AXH - 24R - 36 to 39
9-19-57	AXH - 27R - 21 to 23

UNR (University of Nevada, Reno), black and white, low-sun, vertical, scale 1:14,000

2-4-87	frames 1 167 to 1 180
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REFERENCES

- Hall, C.A., 1973a, Geology of the Arroyo Grande quadrangle, California: California Division of Mines and Geology Map Sheet 24, 1:48,000.
- Hall, C.A., 1973b, Geologic map of the Morro Bay South and Port San Luis quadrangles, San Luis Obispo County, California: U.S. Geological Survey Map MF 511, 1 sheet, 1:24,000.
- Hall, C.A., Jr., Ernst, W.G., Prior, S.W., and Wiese, J.W., 1979, Geologic map of the San Luis Obispo - San Simeon region, California: U.S. Geological Survey Map I-1097, 3 sheets, 1:48,000.
- Hall, C.A., and Prior, S.W., 1975, Geologic map, Cayucos - San Luis Obispo region, California: U.S. Geological Survey Map MF-686, 2 sheets, 1:24,000.
- Hart, E.W., 1985, Fault-rupture hazard zones in California: California Department of Conservation, Division of Mines and Geology Special Publication 42, revised 1985, 24 p.
- Jennings, C.W., 1975, Fault map of California, with locations of volcanoes, thermal springs and thermal wells: California Division of Mines and Geology, California Geologic Data Map Series, Map No. 1 - Faults, volcanoes, thermal springs and wells, 1:750,000.
- Lettis, W.R., and Hall, N.T., 1988, (abstract), Methods for evaluating fault segmentation - an example from central coastal California: Abstracts with Programs, v. 20, no. 3, 84th Annual Meeting, Cordilleran Section, The Geological Society of America, p. 175-176.
- Mezger, E.L., Hanson, K.L., Hall, N.T., and Hunt, T.D., 1987, (abstract), Evidence for Quaternary faulting in Los Osos Valley, San Luis Obispo County, California: Abstracts with Programs, v. 19, no. 6, 83rd Annual Meeting, Cordilleran Section, The Geological Society of America, p. 432.
- Nitchman, S.P., 1988, Tectonic geomorphology and neotectonics of the San Luis Range, San Luis Obispo County, California: unpublished M.S. thesis, University of Nevada, Reno, 120 p.
- PG & E (Pacific Gas and Electric Co.), 1988, Final report of the Diablo Canyon Long Term Seismic Program; 8 chapters; plates.
- Weber, G.E., Lettis, W.R., and Hanson, K.L., 1987, (abstract), Late Pleistocene uplift rates along the central California coast, Cape San Martin to Santa Maria Valley: Abstracts with Programs, v. 19, no. 6, 83rd Annual Meeting, Cordilleran Section, The Geological Society of America, p. 462.